

OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Advanced Subsidiary GCE

CHEMISTRY

Chemistry Foundation

2811

Monday

4 JUNE 2001

...

1 hour 30 minutes

Additional materials.

Calculator

Data Sheet for Chemistry

Candidates answer on the question paper

| | | | | | | | | | | | | |
|----------------|---|------------------|--|--|--|--|---|--|--|--|--|--|
| Candidate Name | Centre Number | Candidate Number | | | | | | | | | | |
| | <table border="1" style="display: inline-table; border-collapse: collapse;"> <tr><td style="width: 15px; height: 15px;"></td><td style="width: 15px; height: 15px;"></td><td style="width: 15px; height: 15px;"></td><td style="width: 15px; height: 15px;"></td><td style="width: 15px; height: 15px;"></td></tr> </table> | | | | | | <table border="1" style="display: inline-table; border-collapse: collapse;"> <tr><td style="width: 15px; height: 15px;"></td><td style="width: 15px; height: 15px;"></td><td style="width: 15px; height: 15px;"></td><td style="width: 15px; height: 15px;"></td><td style="width: 15px; height: 15px;"></td></tr> </table> | | | | | |
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| | | | | | | | | | | | | |

TIME 1 hour 30 minutes

INSTRUCTIONS TO CANDIDATES

- Write your name in the space above.
- Write your Centre number and Candidate number in the boxes above.
- Answer all the questions.
- Write your answers, in blue or black ink, in the spaces on the question paper.
- Read each question carefully and make sure you know what you have to do before starting your answer.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [] at the end of each question or part question.
- The total number of marks for this paper is 90.
- You will be awarded marks for the quality of written communication where an answer requires a piece of extended writing.
- You are advised to show all the steps in any calculations.

| FOR EXAMINER'S USE | | |
|--------------------|-----------|------|
| Qu. | Max. | Mark |
| 1 | 12 | |
| 2 | 9 | |
| 3 | 12 | |
| 4 | 16 | |
| 5 | 9 | |
| 6 | 8 | |
| 7 | 11 | |
| 8 | 13 | |
| TOTAL | 90 | |

This question paper consists of 13 printed pages, 2 lined pages and 1 blank page.

Answer **all** questions.

1 (a) State what is meant by

(i) an *ionic bond*,

.....
[1]

(ii) a *covalent bond*.

.....
[2]

(b) Draw 'dot-and-cross' diagrams to show the bonding in sodium chloride and hydrogen chloride. You should show outer electron shells only.

| | |
|-----------------|-------------------|
| sodium chloride | hydrogen chloride |
|-----------------|-------------------|

[3]

(c) (i) State what is meant by an *orbital*.

.....
[1]

(ii) Draw diagrams to show the shape of an s orbital and of a p orbital.

| | |
|-----------|-----------|
| s orbital | p orbital |
|-----------|-----------|

[2]

- (iii) Complete the table below to show how many electrons **completely** fill each of the following

| | number of electrons |
|-----------------------------|---------------------|
| a p orbital | |
| a d sub-shell | |
| the third shell ($n = 3$) | |

[3]

[Total : 12]

- 2 The table below shows the boiling points of the elements sodium to chlorine in Period 3 of the Periodic Table.

| element | Na | Mg | Al | Si | P | S | Cl |
|------------------|-----|------|------|------|-----|-----|-----|
| boiling point/°C | 883 | 1107 | 2467 | 2355 | 280 | 445 | -35 |
| bonding | | | | | | | |
| structure | | | | | | | |

- (a) (i) Complete the *bonding* row of the table using
- **M** for *metallic bonding*,
 - **C** for *covalent bonding*.
- [1]
- (ii) Complete the *structure* row of the table using
- **S** for a *simple molecular structure*,
 - **G** for a *giant structure*.
- [1]
- (b) State what is meant by *metallic bonding*. You should draw a diagram as part of your answer.

.....

.....

.....[3]

- (c) Explain, in terms of their structure and bonding, why the boiling point of

- (i) phosphorus is much **lower** than that of silicon,

.....

.....

.....[2]

- (ii) aluminium is much **higher** than that of magnesium.

.....

.....

.....[2]

[Total : 9]

3 Hydrogen chloride, HCl, is a colourless gas which dissolves very readily in water forming hydrochloric acid. [1 mol of gas molecules occupy 24.0 dm³ at room temperature and pressure r.t.p.]

(a) At room temperature and pressure, 1.00 dm³ of water dissolved 432 dm³ of hydrogen chloride gas.

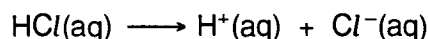
(i) How many moles of hydrogen chloride dissolved in the water?

[1]

(ii) The hydrochloric acid formed has a volume of 1.40 dm³. What is the concentration, in mol dm⁻³, of the hydrochloric acid?

[1]

(b) In solution, the molecules of hydrogen chloride ionise.



Describe a simple test to confirm the presence of chloride ions.

.....

 [2]

(c) Hydrochloric acid reacts with magnesium oxide, MgO, and magnesium carbonate, MgCO₃.

For each reaction, state what you would see and write a balanced equation.

(i) MgO

observation

equation [2]

(ii) MgCO₃

observation

equation [2]

[Total : 8]

4 Sulphur and sulphur compounds are common in the environment.

(a) A sample of sulphur from a volcano contained 88.0% by mass of ^{32}S and 12.0% by mass of ^{34}S .

(i) Complete the table below to show the atomic structure of each isotope of sulphur.

| isotope | number of | | |
|-----------------|-----------|----------|-----------|
| | protons | neutrons | electrons |
| ^{32}S | | | |
| ^{34}S | | | |

[2]

(ii) Define the term *relative atomic mass*.

.....

.....

.....

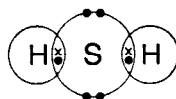
.....[3]

(iii) Calculate the relative atomic mass of the volcanic sulphur. Your answer should be given to three significant figures.

[2]

- (b) Rotten eggs smell of hydrogen sulphide, H_2S , which is a poisonous gas.

A 'dot-and-cross' diagram, showing outer shell electrons only, of a hydrogen sulphide molecule is shown below.



Draw a diagram to show the likely shape and bond angle of a hydrogen sulphide molecule. Explain how you have made your choice.

explanation

.....

.....[3]

- (c) Every year, between 20 and 50 million tonnes of sulphur are released into the atmosphere from the oceans in the form of DMS, a compound of carbon, hydrogen and sulphur. DMS causes the bracing feeling by the sea.

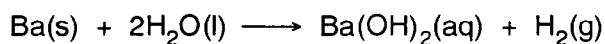
DMS has the percentage composition by mass of C: 38.6%; H: 9.7%; S: 51.7%.

Calculate the empirical formula of DMS.

[2]

[Total : 12]

- 5 The reaction between barium and water is a redox reaction.



- (a) Explain, in terms of electrons, what is meant by

(i) oxidation,

.....[1]

(ii) reduction.

.....[1]

- (b) Which element has been oxidised in this reaction? Deduce the change in its oxidation state.

element

oxidation state changes from *to* [2]

- (c) A student reacted 2.74 g of barium with water to form 250 cm³ of aqueous barium hydroxide.

(i) Calculate how many moles of Ba reacted.

[1]

(ii) Calculate the volume of H₂ that would be produced at room temperature and pressure (r.t.p.). [1 mol of gas molecules occupies 24.0 dm³ at r.t.p.]

[1]

(iii) Calculate the concentration, in mol dm⁻³, of Ba(OH)₂ that was formed.

[1]

(iv) The solution of barium hydroxide is alkaline. Identify a compound that could be added to neutralise this solution and write a balanced equation for the reaction that would take place.

compound

equation[2]

(d) The Group 2 elements react more vigorously with water as the group is descended. This can be explained in part by using ionisation energies.

(i) Define the term *first ionisation energy*.

.....
.....
.....
.....[3]

(ii) Explain, in terms of ionisation energies, why the Group 2 elements become more reactive as the group is descended.

.....
.....
.....
.....
.....[4]

[Total : 16]

- 6 The boiling points of water, hydrogen chloride and argon are shown in Table 7.1 below.

Table 7.1

| | | | |
|---------------------------|------------------|-----|------|
| substance | H ₂ O | HCl | Ar |
| boiling point/°C | 100 | -85 | -186 |
| total number of electrons | 10 | 18 | 18 |

- (a) H₂O, HCl and Ar all have van der Waals' forces.

Outline how van der Waals' forces arise between molecules.

.....

.....

.....

..... [2]

- (b) Liquid H₂O has additional intermolecular forces.

- (i) What are these forces?

..... [1]

- (ii) Explain, with the aid of a diagram, how these forces arise between molecules of H₂O(l).

.....

.....

.....

.....

..... [5]

(c) Liquid HCl also has additional intermolecular forces. What are these forces?

.....[1]

(d) Explain the variation in boiling points shown in Table 7.1.

.....
.....
.....[2]

[Total : 11]

7 The bones in an adult human skeleton have a mass of approximately 9 kg. Of this, 1 kg is calcium.

(a) The calcium in bones is present as calcium ions, Ca^{2+} .

Complete the electronic configurations of the following.

a calcium **atom**: $1s^2$

a calcium **ion**: $1s^2$

[2]

(b) Calculate the approximate number of calcium ions in an adult human skeleton.
[The Avogadro constant, $L = 6 \times 10^{23} \text{ mol}^{-1}$.]

[2]

(c) Suggest why calcium **atoms** are **not** present in a human skeleton.

.....
.....
.....[1]

(d) The calcium in bones can be assumed to be present as calcium phosphate. A phosphate ion has the formula PO_4^{3-} .

(i) What is the formula of calcium phosphate?

.....[1]

(ii) Estimate the percentage, by mass, of calcium phosphate in an adult human skeleton.

[3]

[Total : 9]



RECOGNISING ACHIEVEMENT

Subject: Foundation Chemistry**Code: 2811****Session: June****Year: 2001****Final Mark Scheme 10/6/2001**

| |
|---------------------|
| MAXIMUM MARK |
|---------------------|

| |
|-----------|
| 90 |
|-----------|

RR 10/6/2001

1. (a) State what is meant by**(i)** an *ionic bond*

(electrostatic) attraction between (oppositely charged) ions ✓

[1]

(ii) a *covalent bond*

shared electrons ✓ shared pair ✓

(‘both shared electrons’ scores both marks)

[2]

(b) Draw 'dot-and-cross' diagrams to show the bonding in sodium chloride and hydrogen chloride. You should show outer electron shells only.

NaCl: correct dot and cross ✓

correct charges ✓

HCl: correct dot and cross ✓

[3]

(c) (i) State what is meant by an *orbital*.

a region in which electrons can be found ✓

*(Response must imply the ‘where the electrons are found’.
Do NOT accept ‘path of electron’ or ‘electron arrangement’)*

[1]

(ii) Draw diagrams to show the shape of an s orbital and of a p orbital.

s orbital: circle/ellipse ✓

p orbital: figure of eight/‘egg-timer’ ✓

[2]

(iii) Complete the table below to show how many electrons **completely** fill each of the following

| | number of electrons |
|------------------------|---------------------|
| a p orbital | 2 ✓ |
| a d sub shell | 10 ✓ |
| the third shell | 18 ✓ |

[3]

[Total: 12]

2. The table below shows the boiling points of the elements sodium to chlorine in Period 3 of the Periodic Table.

| element | Na | Mg | Al | Si | P | S | Cl | |
|-----------|----|----|----|----|---|---|----|---|
| bonding | M | M | M | C | C | C | C | ✓ |
| structure | G | G | G | G | S | S | S | ✓ |

- (a) (i) Complete the 'bonding' row of the table using

- **M** for *metallic bonding*
- **C** for *covalent bonding*

[1]

- (ii) Complete the 'structure' row of the table using

- **S** for a *simple molecular structure*
- **G** for a *giant structure*

[1]

- (b) State what is meant by *metallic bonding*. You should draw a diagram as part of your answer.

positive ions/metal ions/cations ✓

surrounded by free/delocalised/sea of electrons ✓

attraction between the above ✓

(Do NOT accept 'holds electrons', 'glue' or 'cement')

[3]

- (c) Explain, in terms of their structure and bonding, why the boiling point of

- (i) phosphorus is much **lower** than that of silicon,

Si has stronger forces/P has weaker forces ✓ (i.e. comparison of forces)

Si: covalent bonds/giant covalent ✓

P: weak forces between molecules/intermolecular forces/van der Waals ✓

[3 → 2 max]

- (ii) aluminium is much **higher** than that of magnesium.

Al has stronger (metallic) bonding ✓

(If 'stronger covalent forces' then WRONG)

Al has 3 outer electrons, Mg has 2/Al has more (outer) electrons than Mg ✓

Al ions are smaller/ more positive/Al ions have a greater charge density ✓

[3 → 2 max]

[Total: 9]

3. Hydrogen chloride, HCl, is a colourless gas which dissolves very readily in water forming hydrochloric acid.

(a) At room temperature and pressure, 1.00 dm³ of water dissolves 432 dm³ of hydrogen chloride gas.

(i) How many moles of hydrogen chloride dissolve in the water?

$$432/24 = 18 \text{ mol} \checkmark$$

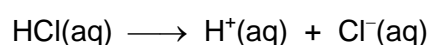
[1]

(ii) The hydrochloric acid formed has a volume of 1.40 dm³. What is the concentration, in mol dm⁻³, of the hydrochloric acid?

$$18/1.4 = 12.9 \text{ mol dm}^{-3} \checkmark \text{ (Look for 12.86) i.e. ans to (a)(i) / 1.4}$$

[1]

(b) In solution, the molecules of hydrogen chloride ionise:



Describe a simple test to confirm the presence of chloride ions.

Add AgNO₃(aq) \checkmark

white (precipitate) \checkmark

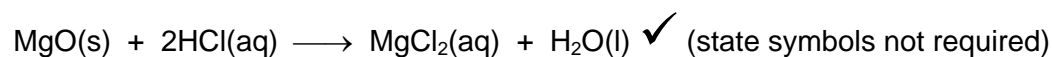
Alternative: "electrolysis giving chlorine \checkmark which bleaches indicator paper \checkmark "

[2]

(c) Hydrochloric acid reacts with magnesium oxide, MgO, and magnesium carbonate, MgCO₃.

For each reaction, state what you would expect to see and write a balanced equation.

(i) MgO dissolves/disappears \checkmark



[2]

(ii) MgCO₃ bubbles/fizzing/CO₂ evolved or formed \checkmark



(state symbols not required)

[2]

[Total: 8]

4. Sulphur and sulphur compounds are common in the environment.

(a) A sample of sulphur from a volcano contained 88% by mass of ^{32}S and 12% by mass of ^{34}S .

(i) Complete the table below to show the atomic structure of these isotopes of sulphur.

| isotope | number of | | |
|-----------------|-----------|----------|-----------|
| | protons | neutrons | electrons |
| ^{32}S | 16 | 16 | 16 |
| ^{34}S | 16 | 18 | 16 |

✓

✓

[2]

(ii) Define the term *relative atomic mass*.

average **atomic** mass/weighted mean/average mass

(*MUST include reference to atoms or isotopes*) ✓

compared with carbon-12 ✓

1/12th of mass of carbon-12/on a scale where carbon-12 is 12 ✓

[3]

(iii) Calculate the relative atomic mass of the volcanic sulphur. Your answer should be given to three significant figures.

$$88 \times 32/100 + 12 \times 34/100 \quad \checkmark$$

$$= 32.2 \quad \checkmark \quad (\text{to 3 sig figs: allow full marks for answer. } 32.24 \text{ (calc) gets 1 mark only})$$

[2]

(b) Rotten eggs smell of hydrogen sulphide H_2S , which is a poisonous gas.

Draw a diagram to show the likely shape and bond angle of a hydrogen sulphide molecule. Explain how you have made your choice.



Watch for bond angle between S-H and lone pair: this is *WRONG*)

electron pair repulsion / 4 electron pairs ✓

[3]

(c) Calculate the empirical formula of DMS.

$$\text{mole ratio: } \frac{38.6}{12} \text{ C} : \frac{9.7}{1} \text{ H} : \frac{51.7}{32.1} \text{ S} \quad \checkmark$$

i.e. correct use of '12', '1' and 32.1.

$$= 2 : 6 : 1 \text{ / empirical formula } = \text{C}_2\text{H}_6\text{S} \quad \checkmark$$

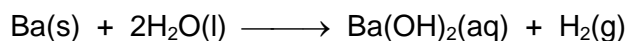
(If 16 is used for S, then emp formula $\longrightarrow \text{CH}_3\text{S}$.)

OR C: 6 and S: 16, $\longrightarrow \text{C}_2\text{H}_3\text{S}$ Worth 1 mark)

[2]

[Total: 12]

5. The reaction between barium and water is a redox reaction.



(a) Explain, in terms of electrons, what is meant by

(i) oxidation

loss (of electrons) ✓

[1]

(ii) reduction

gain (of electrons) ✓

[1]

(b) Which element has been oxidised in this reaction. Deduce the change in its oxidation state.

Ba ✓

0 to +2 (needs to be completely correct) ✓

[2]

(c) A student reacted 2.74g of barium with water to form 250 cm³ of aqueous barium hydroxide.

(i) Calculate how many moles of Ba reacted.

2.74/137 / 0.0200 mol ✓

[1]

(ii) Calculate the concentration, in mol dm⁻³, of Ba(OH)₂ was formed.

ans to (c)(i) x 4 mol dm⁻³ ✓ correct answer: 0.0800 mol dm⁻³

[1]

(iii) Calculate the volume of H₂ that would be produced at room temperature and pressure (r.t.p.). [1 mol of gas molecules occupies 24.0 dm³ at r.t.p.]

ans to (c)(i) x 24.0 dm³ ✓ correct answer: 0.480 dm³ / 480 cm³

[1]

(iv) The solution of barium hydroxide is alkaline. Identify a compound that could be added to neutralise this solution and write a balanced equation for the reaction that would take place.

any acid ✓

balanced equation to match acid chosen ✓

[2]

(d) The Group 2 elements react more vigorously with water as the group is descended. This can be explained in part by using ionisation energies.

(i) Define the term *first ionisation energy*.

Energy change when **each atom in 1 mole** ✓

of **gaseous atoms** ✓

loses an electron ✓ (to form 1 mole of gaseous 1+ ions).

(or 1 mole of gaseous atoms loses 1 mole of electrons)

[3]

(ii) Explain, in terms of ionisation energies, why the Group 2 elements become more reactive as the group is descended.

ionisation energy decreases ✓

electron is further from nucleus/ electron in a different shell ✓

electron experiences **more** shielding ✓

(Watch out for **comparison: 'shielding' alone is not enough for mark**)

nuclear attraction decreases/distance or shielding outweighs nuclear attraction/

electron is easier to lose/effective nuclear charge decreases ✓

[4]

[Total: 16]

6. The boiling points of water, hydrogen chloride and argon are shown in Table 7.1 below.

| | | | |
|----------------------------------|------------------|-----|------|
| substance | H ₂ O | HCl | Ar |
| boiling point /°C | 100 | -85 | -186 |
| number of electrons per molecule | 10 | 18 | 18 |

(a) H₂O, HCl and Ar all have van der Waals' forces.

Outline how van der Waals' forces arise between molecules.

oscillating/changing/temporary/transient dipole on one atom ✓

causes an induced/resultant dipole on another molecule/atom ✓

[2]

(b) Liquid H₂O has additional intermolecular forces.

(i) What are these forces?

H₂O: Hydrogen bonds ✓

[1]

(ii) Explain, with the aid of a diagram, how these forces arise between molecules of H₂O(l).

electronegativity/polarity: O more electronegative than H

/O is very electronegative ✓

H₂O have polar molecules ✓ (could be from diagram)

H bonding: dipoles in water correctly shown ✓

H-bond between H and an O in another H₂O molecule ✓

Involvement of lone pair on oxygen ✓

[5]

(c) Liquid HCl also has additional intermolecular forces. What are these forces?

permanent dipole-dipole interactions ✓

[1]

(d) Explain the variation in boiling points shown in Table 7.1.

H-bonds are the strongest ✓

van der Waals' forces/ forces between Ar atoms are the weakest ✓

(i.e. responses should confirm order of strength of 3 types of forces)

[2]

[Total: 11]

7. The bones in an adult human skeleton have a mass of approximately 9 kg. Of this, 1 kg is calcium.

(a) The calcium in bones is present as calcium ions, Ca^{2+} .

Complete the electronic configurations of the following.

a calcium atom: $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$ ✓

a calcium ion: $1s^2 2s^2 2p^6 3s^2 3p^6$ ✓

[2]

(b) Calculate the approximate number of calcium ions in an adult human skeleton.

moles of Ca = $1000/40.1 = \text{approx } 25$ ✓

(If atomic number is used for Ca (20), then 1st mark is lost but 2nd mark gained)

number of calcium ions = $6 \times 10^{23} \times 25 = 1.5 \times 10^{25}$ ✓

[2]

(c) Explain why calcium atoms are **not** present in a human skeleton?

Ca^{2+} ions more stable than Ca/

Ca atoms react with water/too reactive ✓

[1]

(d) The calcium in bones can be assumed to be present as calcium phosphate. A phosphate ion has the formula PO_4^{3-} .

(i) What is the formula of calcium phosphate?

$\text{Ca}_3(\text{PO}_4)_2$ ✓

[1]

(ii) Estimate the percentage, by mass, of calcium phosphate in an adult human skeleton.

$\text{Ca}_3(\text{PO}_4)_2$ has a molar mass of $(40.1 \times 3) + (31 + 16 \times 4) \times 2 = 310.3 \text{ g mol}^{-1}$ ✓

mass of $\text{Ca}_3(\text{PO}_4)_2$ in bone = $310.3/120.3 = 2.58 \text{ kg}$ ✓

% of $\text{Ca}_3(\text{PO}_4)_2$ in bone = $(2.58/9) \times 100 = 29\%$ ✓ (28.6%)

(i.e. 1 mark for molar mass of ans to (d)(i).

1 mark for multiplying by 100/9

1 mark for proportion idea i.e dividing by 120.3)

CaPO_4 gives M_r of 135.1/135.

[3]

[Total: 9]

-
8. Compare and explain the electrical conductivity of sodium chloride, diamond and graphite. In your answer, you should consider the structure and bonding of each of these materials.

In this question, 2 marks are available for the quality of written communication.

NaCl: giant ✓ ionic ✓ lattice

fixed ions in solid ✓

does not conduct when solid ✓

does conduct when aqueous/ molten ✓

mobile ions in solution or when molten ✓

6 marks max 5

Diamond **OR** graphite:

covalent ✓ giant ✓

Diamond: no free electrons/ions/charge carriers/all electrons involved in bonding ✓

does not conduct at all (*NOT poor conductor*) ✓

Graphite: layered structure ✓

delocalised electrons (between layers) ✓

conducts (by movement of delocalised electrons) ✓

7 marks max 6

Q – legible text with accurate spelling, punctuation and grammar ✓

Clear, well-organised, using specialist terms 5 or more ✓

[Total: 13]